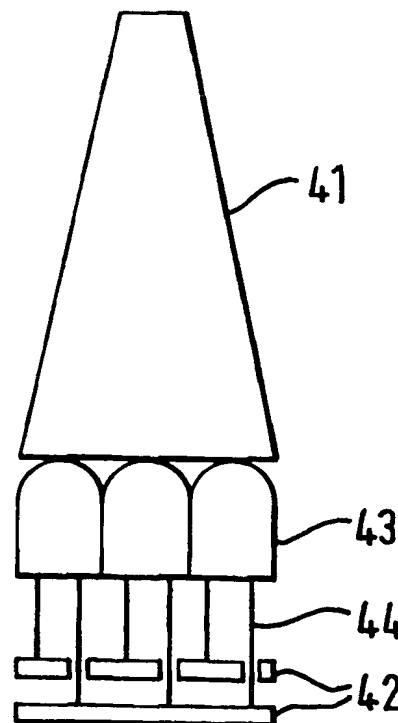


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<p>(21) International Application Number: PCT/GB98/02905</p> <p>(22) International Filing Date: 25 September 1998 (25.09.98)</p> <p>(30) Priority Data:</p> <table border="0"> <tr> <td>9720443.2</td> <td>25 September 1997 (25.09.97)</td> <td>GB</td> </tr> <tr> <td>9806046.0</td> <td>20 March 1998 (20.03.98)</td> <td>GB</td> </tr> </table> <p>(71) Applicant (for all designated States except US): UNIVERSITY OF BRISTOL [GB/GB]; Research Support & Industrial Liaison Office, Senate House, 3rd floor, Tyndall Avenue, Bristol BS8 1TH (GB).</p> <p>(72) Inventors; and</p> <p>(75) Inventors/Applicants (for US only): MILLS, Robin, Walter [GB/GB]; 9 Kempsfield, Devizes, Wiltshire SN10 5AX (GB). JANDT, Klaus, Dieter [GB/GB]; 21 Cranmoor Green, Bristol BS35 4QF (GB).</p> <p>(74) Agent: HOGG, Jeffery, Keith; Withers & Rogers, 4 Dyer's Buildings, Holborn, London EC1N 2QP (GB).</p>		9720443.2	25 September 1997 (25.09.97)	GB	9806046.0	20 March 1998 (20.03.98)	GB	<p>(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p>Published</p> <p><i>With international search report.</i></p> <p><i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>
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(54) Title: OPTICAL IRRADIATION DEVICE**(57) Abstract**

An optical irradiation device incorporating a cluster of LEDs (11, 43) arranged so that shaped facets of adjacent LEDs come together to increase the packing density of LEDs in the cluster. A light guide (41) collects light emitted by the LEDs. Two or more light guides (41) and LED clusters (43) may be arranged in series to produce a single light beam. A heat pipe (45) is provided to conduct heat away from the LEDs (43). The heat pipe (56) may be annular and contain an inner storage space for batteries (60) or the like.



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OPTICAL IRRADIATION DEVICE

TECHNICAL FIELD

This invention relates to an optical irradiation device, especially a compact portable irradiation device suitable for use as a light polymerisation source.

It has already been proposed to use light-emitting diodes LEDs in a hand held device to produce a focused beam of light to cure dental materials. Blue light at a peak wavelength of about 470nm is used to harden dental polymers which contain camphoroquinone as the photoinitiator in a methacrylate polymerisation process. However, there is a problem in producing a sufficient level of irradiance even with a clustered array of LEDs, to cure the known dental polymers in the recommended time. At the lower levels of irradiance available generally below 300mW/sq.cm, longer curing times have to be allowed, which reduces the efficiency of the dental treatment delivered.

DISCLOSURE OF THE INVENTION

An object of the present invention is to provide an optical irradiation device that employs LEDs, and thereby has the benefits of compactness, portability, ruggedness and long

life, but which also produces improved levels of irradiance at and above 300mW/sq.cm.

According to a first aspect of the invention, LEDs are clustered in an irradiation device by forming shaped facets on adjacent LEDs which allow them to adjoin more closely than they would otherwise with conventional spherical outer surfaces as manufactured currently.

According to a second aspect, the invention consists in a tapered light guide for an optical irradiation device, which light guide is tapered from its input end to its output end and has an intermediate region of minimum diameter in which a bend is formed.

According to a third aspect, the invention consists in an optical irradiation device employing LEDs and incorporating a heat pipe to cool the LEDs.

According to a fourth aspect, the invention consists in a heat pipe comprising inner and outer walls that extend longitudinally from one end of the heat pipe to the other and define an annular space therebetween containing a material that serves to absorb heat by a phase change, the annular space being divided by internal walls into a plurality of fluid flow channels that extend longitudinally between said

ends, some of said channels being adapted to conduct the liquid/vapour phase of said material from the hot end of the heat pipe to the cold end, and other channels being adapted to return said liquid phase from the cold end of the pipe to the hot end.

According to a fifth aspect, the invention consists in an irradiation device employing LEDs and a tapered light guide to collect radiation emitted by the LEDs and deliver this to an output beam, wherein two or more tapered light guides are arranged in series so that successive guides receive radiation from preceding guides, and a group of LEDs is provided at the input end of each guide, each successive guide preferably being provided with a ring of LEDs around the output end of the preceding guide.

The first aspect of the invention means that LEDs occupy more of the available space, and a fixed number produce a higher radiant intensity. Thus, smaller numbers of LEDs can be used to produce a desired level of irradiance, which in turn reduces the power required to drive the device and the heat generated by it. Furthermore, the device can be made more compact. Packing of the LEDs in this way may involve a slight reduction in the output of each LED, but the more effective packing density produces an overall increase in irradiance.

Typically, a central LED might have a polygonal outer surface, and a first ring of LEDs would be arranged around it, each with a flat face to abut a corresponding face of the central LED and possibly each having a pair of radiating side faces which abut adjacent LEDs in the first ring. Furthermore, a second or more rings of LEDs could be arranged concentrically with the first ring, each with respective adjacent flat side faces abutting one another and possibly with inwardly diverted faces abutting respective outwardly directed faces of the LEDs of the inner ring. Alternatively, a single ring or two or more concentric rings of LEDs could be used without a central LED.

DESCRIPTION OF THE DRAWINGS

The invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a schematic cross-section through a first embodiment of the invention comprising a cluster of hexagonal section LEDs;

Figure 2 is a schematic cross-section through a second embodiment of the invention comprising a cluster of an inner group of LEDs and an outer ring of LEDs;

Figure 3 is a schematic cross-section through a third embodiment of the invention comprising a cluster of two rings of LEDS;

Figure 4 is a schematic side elevation of a fourth embodiment of the invention;

Figure 5 is a schematic longitudinal section through a fifth embodiment of the invention;

Figure 6 is a schematic longitudinal section through a sixth embodiment of the invention;

Figure 7 is a schematic cross-section through a bundle of light guide fibres with modified sections;

Figure 8 is a schematic side elevation of a tapered light-guide according to another embodiment of the invention; and

Figure 9 is a schematic cross-section through a heat pipe according to the invention.

MODE OF CARRYING OUT THE INVENTION

In a typical optical irradiation device according to the invention, a plurality of LEDs are clustered together so as to

direct emitted radiation into a single beam. A cluster of LEDs 43 is shown in side view in Figure 4, and in plan view or cross-section in Figures 1 to 3. Each LED comprises a light-emitting semiconductor Pn junction (not shown) which is encapsulated in an outer plastics envelope, the profile of which is shown in the drawings. The sides of the LED envelope are shaped to allow the LEDs to be clustered together more closely at their bases, thereby increasing the ratio of occupied to unoccupied space in the cluster of LEDs. The tips of the LEDs are substantially spherical and transmit the radiation to form the beam.

In the embodiment of the invention illustrated in Figure 1 the outer envelope of the LEDs is hexagonal in cross-section, and the LEDs are clustered in the manner of a honeycomb as shown, with adjacent facets abutting one another.

In the second embodiment of the invention illustrated in Figure 2, a central LED 21 of hexagonal cross-section has facets which abut adjacent facets of six LEDs 22 in a first ring of LEDs with radially extending side facets that allow adjacent LEDs in the ring to abut one another. A second ring of LEDs 23 is arranged around the first ring of LEDs, and these LEDs 23 have radially extending side facets that allow adjacent LEDs in the ring to abut one another.

In a third embodiment of the invention shown in Figure 3, an inner ring of nine LEDs 31 in a first ring is contained within a second ring of LEDs 32, and radially extending side facets of the LEDs in both rings allow adjacent LEDs in each ring to abut one another.

Both the second embodiment of Figure 2 and the third embodiment of Figure 3 may be modified by the addition of one or more further concentric rings of LEDs. Also, the circumferential facets of the LEDs of each ring may be shaped to abut similarly shaped circumferential facets of the adjacent ring of LEDs.

In yet another embodiment, the central group of LEDs 21,22 of Figure 2 may be replaced by the same number of LEDs in a honeycomb cluster. Yet another embodiment may consist of the single ring of LEDs 31 shown in Figure 3. It will be appreciated in all three illustrated embodiments, the LEDs are mounted in a substantially flat plane.

In modifying the conventional optical sphere shape of the outer plastics envelope of a LED care has to be taken to preserve as much as possible of the focusing effect of the envelope to maximise the total irradiance. However, because the envelope of existing LEDs have a tapered shape to assist their removal from the mould during manufacture, the shaped

side facets can be formed around the broader base of the LED to change its cross-section, for example to become hexagonal, but with these facets having a reducing effect on the shape of the envelope towards its tip where the focusing effect of the envelope is concentrated. Thus the invention can employ existing LEDs and modify their shape in a secondary manufacturing process, for example, using jigs, or the invention can employ LEDs which have been specially manufactured with the required outer envelope shape to accommodate better clustering.

The shaped facets of the LEDs may be polished to enhance reflection and help reduce any loss of optical powers. Additionally, a reflective metallic film may be applied to the shaped facets to further enhance reflection.

The LEDs may also incorporate a microlens or microlens array to aid collimation of the beam.

The electrical connections of the LEDs, known as lead frames 44, are connected to respective positive and negative power terminals or bus bars 42. Preferably, these terminals are adapted to serve the dual function of heat sinks to help remove heat generated by the LEDs 43. Thus, the terminals are formed of a good thermal conductor such as copper, and are located in the optimum location relative to the LEDs and the

external surfaces of the device. In one particular embodiment most suited to the LED array of Figure 3, the terminals 42 take the form of two concentric rings, each lying adjacent to the bases of one ring of LEDs 31 or 32. Preferably, the negative terminal is the outer one because the negative lead frames 44 of the LEDs generally get hotter than the positive lead frames 44.

The typical optical irradiation device according to the invention also preferably incorporates a tapered light guide, shown as guide 41 in Figure 4, to collect light emitted by the LEDs and deliver this as an output beam. It is known to use light guides with adiabatic optical tapers in optical irradiation devices so that there is total internal reflection of the light as it is conducted from the light source to the output. However, an advantage of the invention is that the more compact cross-section of the LED cluster means that the diameter at the input end of the light guide can be smaller, and thus a smaller angle of adiabatic taper (i.e. the ratio of the diameter of the input end to the output end of the light guide) can be provided in the light guide with the consequent more efficient transmission of radiant energy and increased illuminance. This improvement is most marked compared with a conventional approach of simply increasing the numbers of LEDs in a cluster at ever increasing diameters with decreasing

beneficial effect on illuminance and increasing detrimental effect on compactness, heat generation and cost.

In another embodiment of the invention, illustrated in Figure 6, two or more adiabatic tapered light guides 41 are arranged in series, each with a corresponding cluster of LEDs 43, but with successive clusters forming a ring around the end of one light guide as it connects to the next. Alternatively, each successive ring of LEDs 43 may be replaced by just one or a fewer number of LEDs. This arrangement allows the overall diameter of the device to be kept relatively small as the LED clusters 43 are arranged in groups along the length of the device.

In the preferred embodiment of Figure 4, a single tapered light guide 41 is provided. If required, the light guide can be curved along its length, as shown in Figure 5, to direct the output beam to suit a particular application, this being a known practice with existing light guides. The light guide may be machined from cast acrylic plastic and bent, or could be made from glass or other optically transparent materials.

An alternative light guide is illustrated in Figure 8 in which the bend in the light guide 41 is provided at a waisted section 46 in its length which reduces to a minimum diameter

before widening again to a larger diameter towards its output end. By forming the bend at the minimum diameter, the light transmission losses of the light guide caused by the bend are reduced, but the effective cross-sectional area of the output beam is maintained at the required level.

Fused fibre-bundle light guides have the advantage of individual fibres being of a relatively small diameter so that they can be bent over a tighter radius without the greater losses associated with larger diameter fibres when bent over the same radius. However, conventional fused-fibre bundles have the disadvantage of a packing fraction loss, that is, the outer cladding of the fibre uses up a significant proportion of the cross-section of the light guide into which light from the semiconductor array is directed, thus reducing the amount of transmitted radiation available from the semiconductor source. Preferably, therefore, in one embodiment of the invention, illustrated in Figure 7, the guide comprises a few shaped fibres 61 placed adjacent to each other and fused together. A guide of this design is manufactured by MicroQuartz Sciences Inc. of Phoenix, Arizona, USA. In this way, the diameter of each fibre is smaller than a single homogeneous guide rod so that they allow greater light transmission on bending around the same bend radius, but also the packing fraction is also greatly reduced over conventional

fibre guides, resulting in a greater than 90% core availability at the input end of the guide.

In another embodiment of the invention, a graded-index optical light guide is used. A graded-index light guide has no sudden interface between the cladding and the core. Instead, the refractive index varies either radially or axially. In one embodiment, the gradient of the refractive index of the light guide varies both radially and axially so that the light energy is favourably manipulated. A guide that uses a stepped index could also be used with the same axial and radial variation in refractive index. In this way, the numeric aperture can be varied at either end of the guide to achieve the desired transmission.

In other embodiments of the invention, instead of providing a single tapered light guide, each LED or groups of LEDs could be provided with its own light guide fibre incorporating an adiabatic optical taper, and the output ends of these fibres could be collected together to form a single output beam. The input end of the fibre would be moulded optically to the adjacent LED or group of LEDs for efficient transmission of radiation. In this way, the diodes can be spaced more widely to dissipate unwanted heat. In yet another embodiment of the invention, each LED could be adjusted so that its outer envelope is extended into a fibre light guide which

incorporates an adiabatic optical taper. In yet another embodiment, the section of the fibres may be modified so that shaped faces of the fibres fit together to reduce the interstitial space. One embodiment of this design could be as shown in Figure 7.

The light guide or light guides used according to the invention may be formed with an outer metallic coating to improve its performance.

It will be appreciated that the irradiance of the device according to the invention can be varied by varying the input power, number of LEDs, or by varying the adiabatic taper of the light guide.

Cooling of the LED cluster can be aided according to another feature of the invention by arranging that the electrical connections of each LED are thermally connected to one or more heat pipes. Conventional LED irradiation devices usually include a heat sink to conduct away the heat from the LED chips. Heat sinks are generally slow and inefficient in conducting heat away from a heat source compared with heat pipes. Heat pipes conduct heat away rapidly by using the latent heat of a substance, such as water, which is vaporised by the heat from the source. The vapour moves at high speed to the cooler end of the heat pipe and condenses. Heat pipes

are unique in their ability to conduct heat rapidly in this way.

Figure 5 shows a device according to the invention which incorporates a heat pipe 45 as a single lumen in the main body 46 of the device. The hotter of the LED leads is preferably placed nearer the heat pipe 45 or outer case 47 of the LED cluster so that the heat path of the hotter lead is shorter. A thermal connector 48 may be provided between the LEDs 43 and the end of the heat pipe 45. If required, additional forced cooling means may be used for example, a fan 49 or Peltier device 50 in juxtaposition to the pipe. In addition, a heat sink 51 may be provided.

Because of the greater cooling ability of heat pipes, they allow the LEDs to be driven in such a manner as to produce more radiation, and thus allows a more powerful device to be manufactured.

For portable use, the LEDs are operated from batteries 52, which are located in a hand grip 53 attached to the body 46, in Figure 5. However, the heat pipe design can be modified as shown in Figure 9 to accommodate batteries. The heat pipe consists of two concentric heat conducting tubes 55, 56 with a folded interstitial heat conduction element 57 between these tubes similar in appearance to a length of corrugated

sheet rolled into a tube. This lies within the concentric tubes. The wicks 58 of the heat pipe can then be placed in alternative grooves in the corrugated sheet, while the empty grooves 59 allow for the rapid movement of the vapour formed at the warmer end of the heat pipe.

By designing the heat pipe in this way batteries, capacitors, supercapacitors or other energy source 60 can be located within the inner wall 55 of the heat pipe.

In some embodiments, for example, where there are a large number of LEDs, a heat sink 51 may be necessary in addition to the heat pipe 45. The intermittent use of an LED irradiation device for dental curing, means that with careful design, a heat sink may be omitted. If cooling to below the ambient temperature is required, such as may be the case in extreme environments, a Peltier device 50 may be added to the heat pipe, although a Peltier device will result in a greater consumption of power and a requirement for greater heat dissipation.

The wavelengths of the LED used will depend upon the applications of the device. A LED emitting blue light with a peak wavelength of about 470nm is used to harden dental polymers, but a LED emitting red light may be useful for photodynamic therapy, for example, cancer therapy.

The wavelength of light emitted by the LEDs may be modified in a light guide by doping the material from which it is composed with fluorescent material. This can serve to lengthen the wavelength of the emitted light so as to suit the particular application.

The choice of LED is also important in terms of its construction, diameter, irradiance and light angular spread pattern. From a range of known LEDs the best available choice has been determined as that with a 3mm diameter rather than a 5mm diameter and an angular spread of 30 degrees rather than 15 or 45 degrees. Nichia is the manufacturer of these LEDs.

It will be appreciated that the term "light-emitting diode-LED" as used herein also includes laser diodes.

LEDs in the devices according to the invention may be operated in a pulsed mode or modulated mode to vary the output radiation intensity to suit the application, and multiple clusters of LEDs, such as in the embodiment of Figure 6, may each be generated in a different mode.

The power supply for the LEDs of the device according to the invention could be mains power, battery power, capacitor,

supercapacitor, solar power, clockwork generator or generator powered by the mechanical effort of the operator or assistant.

In one embodiment, a capacitor or supercapacitor could be used to power the array having advantages over conventional rechargeable sources such as batteries. Capacitors can be virtually instantaneously recharged between one or more curing cycles of operation when the unit is connected to a power source.

The power supply for the device may be re-chargeable, and may be designed to make automatic electrical contact with the charging means of a base unit when engaged with the latter in the manner of a cordless telephone handset.

CLAIMS

1. An optical irradiation device comprising an array of light-emitting diodes (LEDs) clustered so that radiation they emit is directed into a beam characterised in that each LED is formed with multiple facets such that the facets of adjacent LEDs adjoin one another in close proximity throughout their length.
2. A device as claimed in claim 1 in which the facets of adjacent LEDs extend substantially parallel to one another.
3. A device as claimed in claims 1 or 2 in which the facets of adjacent LEDs abut one another.
4. A device as claimed in any one of the preceding claims in which LEDs are arranged in a ring with side facets of adjacent LEDs adjoining one another.
5. A device as claimed in claim 4 in which LEDs are arranged in concentric rings with side facets of adjacent LEDs in each ring adjoining one another.
6. A device as claimed in claim 5 in which the LEDs of adjacent rings have radially directed facets adjoining one another.

7. A device as claimed in any one of claims 4 to 6 in which a single LED is located within said ring or innermost concentric ring.
8. A device as claimed in claim 7 in which said single LED has radially directed facets that adjoining facets of the LEDs in said ring or innermost concentric ring.
9. A device as claimed in any one of the preceding claims in which the LEDs are regular polygons in cross-section.
10. A device as claimed in claim 9 in which the LEDs are hexagonal in cross-section.
11. A device as claimed in any one of the preceding claims in which the facets of the LEDs are polished.
12. A device as claimed in any one of the preceding claims in which the facets of the LEDs are provided with a reflective coating.
13. A diode adapted for use in an optical irradiation device as claimed in any one of claims 1 to 12.
14. A device as claimed in any one of the preceding claims, including a light guide for collecting light from the cluster of light emitting diodes.

15. A device as claimed in any one of claims 1 to 13, wherein a light guide is provided for each light emitting diode in the cluster.
16. A device as claimed in any one of the preceding claims including a light guide for collecting light from the cluster of LEDs, the light guide having an index that varies from one part to another so as to manipulate the light.
17. A device as claimed in any one of the preceding claims including a light guide that consists of a few fibres formed individually before being bundled together.
18. A device as claimed in any one of the preceding claims including a light guide consisting of shaped fibres packed together so that the packing fraction is reduced.
19. An irradiation device employing LEDs and a tapered light guide to collect radiation emitted by the LEDs and deliver this to an output beam, characterised in that two or more tapered light guides are arranged in series so that successive guides receive radiation from preceding guides, and an LED or group of LEDs is provided at the input end of each guide.
20. A device as claimed in claim 20 in which each successive guide is provided with a ring of LEDs around the output end of the preceding guide.
21. A device as claimed in any one of the preceding claims in which the heat is removed from the LEDs by a heat pipe.

22. A device as claimed in claim 21 in which a plurality of heat pipes is used to transfer heat from the LEDs.
23. A device as claimed in claim 21 or 22 in which an annular heat pipe is used so that it can contain energy storage means.
24. A device as claimed in any one of the preceding claims, including a Peltier device to cool the LEDs.
25. A device as claimed in any one of the preceding claims having a pistol grip to contain energy storage means.
26. A device as claimed in any one of the preceding claims, including a capacitor or supercapacitor to power the device.
27. An optical irradiation device comprising a plurality of LEDs and a heat pipe to cool the LEDs.
28. A hand-held device for curing dental materials including an optical irradiation device as claimed in any one of the preceding claims.

29. A heat pipe comprising inner and outer walls that extend longitudinally from one end of the heat pipe to the other and define an annular space therebetween containing a material that serves to absorb heat by a phase change, the annular space being divided by internal walls into a plurality of fluid flow channels that extend longitudinally between said ends, some of said channels being adapted to conduct the liquid/vapour phase of said material from the hot end of the heat pipe to the cold end, and other channels being adapted to return said liquid phase from the cold end of the pipe to the hot end.

30. A tapered light guide for an optical irradiation device, which light guide is tapered from its input end to its output end and has an intermediate region of minimum diameter in which a bend is formed.

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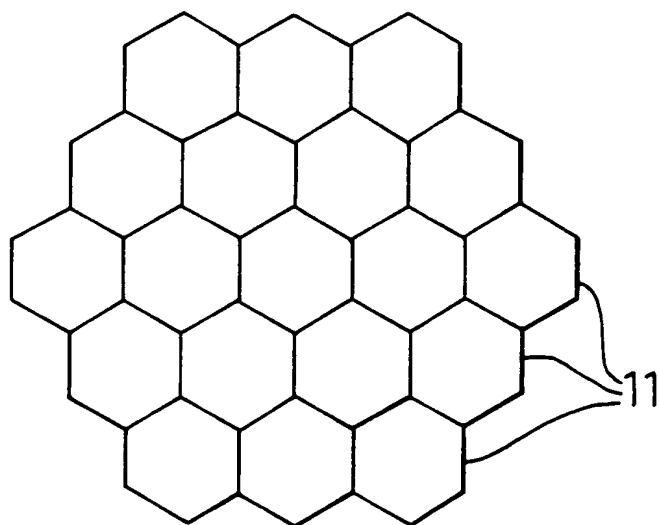


FIG. 1

FIG. 2

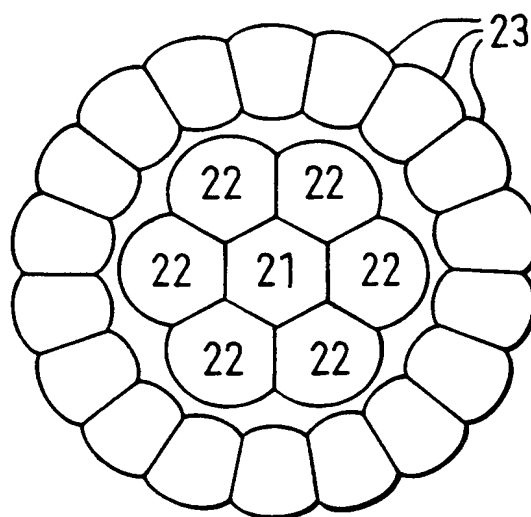
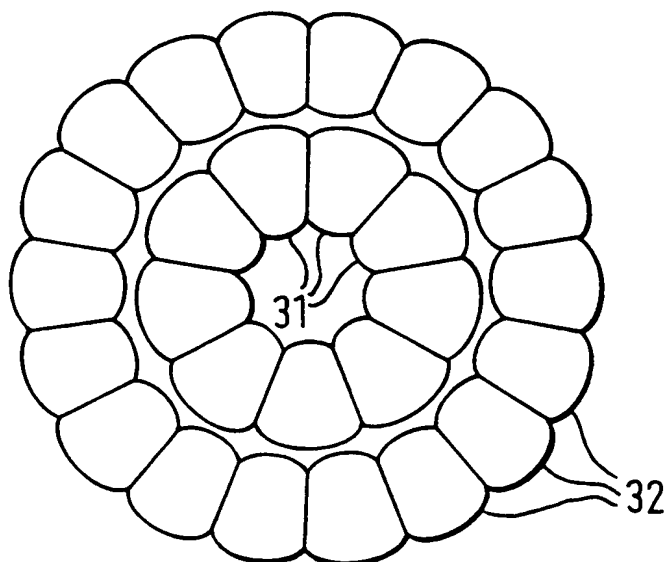


FIG. 3



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FIG. 4

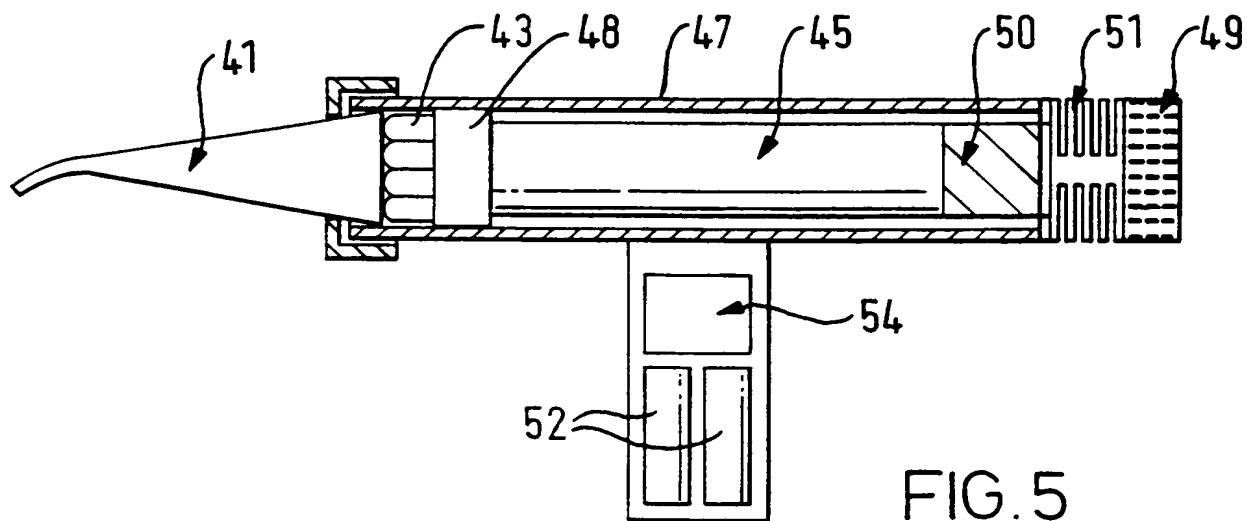
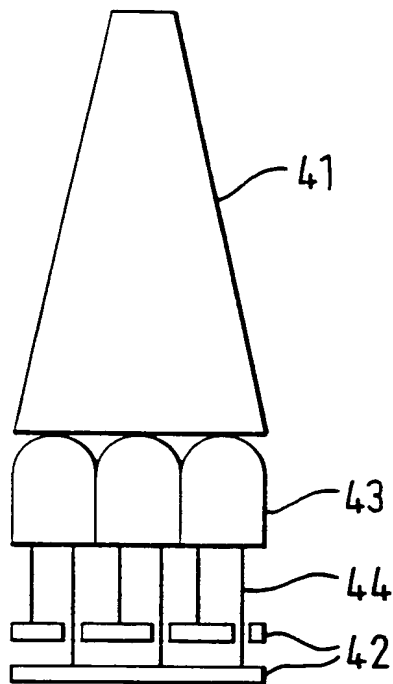


FIG. 5

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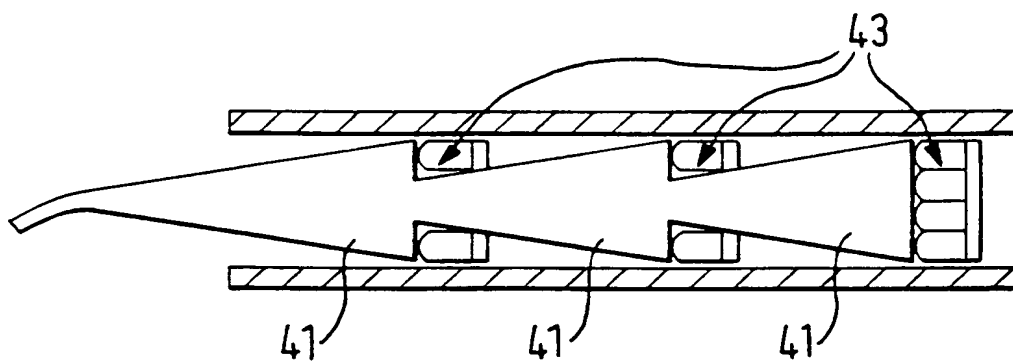


FIG. 6

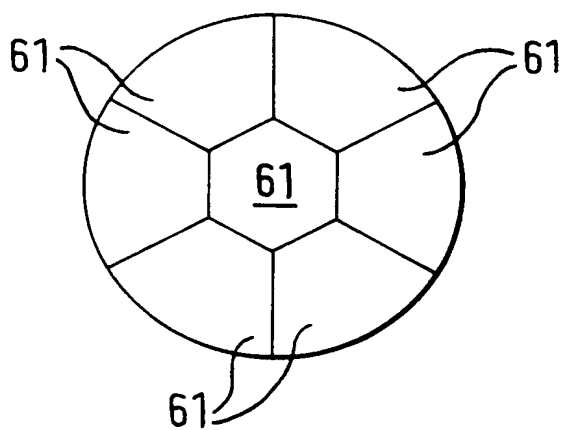


FIG. 7

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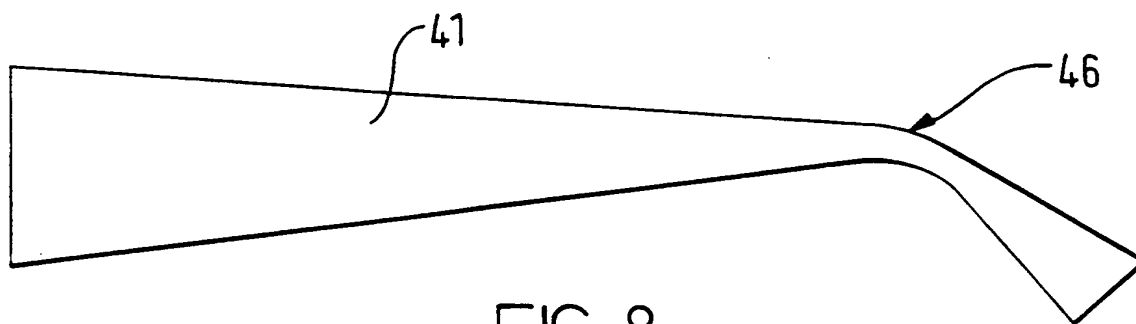


FIG. 8

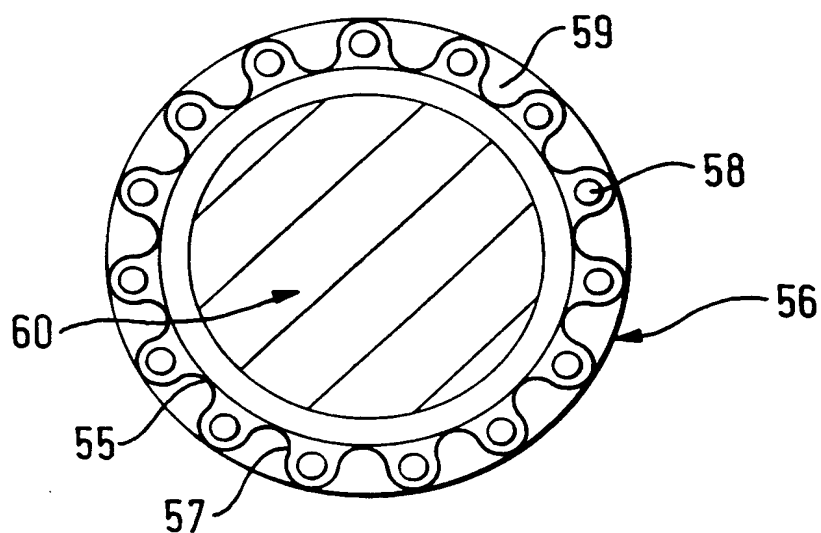


FIG. 9

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 98/02905

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 H01L33/00 H01L25/13 A61C19/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H01L A61C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 191 500 A (ESPE PHARM PRAEP) 20 August 1986 see abstract	30
A	----- PATENT ABSTRACTS OF JAPAN vol. 011, no. 011 (E-470), 13 January 1987 -& JP 61 185980 A (STANLEY ELECTRIC CO LTD), 19 August 1986 see abstract; figures	1-3, 9, 10
A	----- PATENT ABSTRACTS OF JAPAN vol. 096, no. 009, 30 September 1996 -& JP 08 116093 A (FUJITSU LTD), 7 May 1996 see abstract; figures ----- -/-	1, 2, 9, 10

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

Date of the actual completion of the international search

22 January 1999

Date of mailing of the international search report

04/02/1999

Name and mailing address of the ISA

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Authorized officer

De Laere, A

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 98/02905

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>PATENT ABSTRACTS OF JAPAN vol. 013, no. 097 (E-723), 7 March 1989 & JP 63 271983 A (MITSUBISHI CABLE IND LTD), 9 November 1988 see abstract</p> <p style="text-align: center;">----</p>	
A	<p>PATENT ABSTRACTS OF JAPAN vol. 097, no. 005, 30 May 1997 -& JP 09 010238 A (OSADA RES INST LTD), 14 January 1997 see abstract</p> <p style="text-align: center;">----</p>	<p>1,4-7, 13,14, 19,28</p>
A	<p>PATENT ABSTRACTS OF JAPAN vol. 096, no. 001, 31 January 1996 -& JP 07 240536 A (SHIMADZU CORP), 12 September 1995 see abstract; figures</p> <p style="text-align: center;">----</p>	<p>1,4, 13-15,17</p>
A	<p>US 5 634 711 A (KAYSER ROY ET AL) 3 June 1997</p> <p>see column 3, line 38 - column 4, line 49 see column 8, line 40-48 see column 9, line 15-25</p> <p style="text-align: center;">-----</p>	<p>1,13,14, 21, 26-28,30</p>

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 98/02905

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0191500 A	20-08-1986	US 4723825 A	09-02-1988
US 5634711 A	03-06-1997	US 5420768 A	30-05-1995
		AU 7737894 A	03-04-1995
		CA 2149339 A	23-03-1995
		WO 9507731 A	23-03-1995

PATENT COOPERATION TREATY

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

United States Patent and Trademark
Office
(Box PCT)
Crystal Plaza 2
Washington, DC 20231
ÉTATS-UNIS D'AMÉRIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 04 June 1999 (04.06.99)	Applicant's or agent's file reference JKH/BA/UNIBR17
International application No. PCT/GB98/02905	Priority date (day/month/year) 25 September 1997 (25.09.97)
International filing date (day/month/year) 25 September 1998 (25.09.98)	
Applicant MILLS, Robin, Walter et al	

1. The designated Office is hereby notified of its election made:

☒ in the demand filed with the International Preliminary Examining Authority on:
20 April 1999 (20.04.99)

☐ in a notice effecting later election filed with the International Bureau on:

2. The election ☒ was

☐ was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740.14.35	Authorized officer Lazar Joseph Panakal Telephone No.: (41-22) 338.83.38
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TRAITE DE COOPERATION EN MATIERE DE BREVETS

PCT**NOTIFICATION CONCERNANT UNE DEMANDE
INTERNATIONALE CONSIDEREE COMME
RETIREE**

(article 14.1),3) ou 4) et règle 29.1 du PCT)

Expéditeur: le BUREAU INTERNATIONAL

Destinataire:

United States Patent and Trademark
Office
(Box PCT)
Crystal Plaza 2
Washington, DC 20231
ÉTATS-UNIS D'AMÉRIQUE

en sa qualité d'office désigné

Date d'expédition (jour/mois/année) 14 avril 1999 (14.04.99)	NOTIFICATION IMPORTANTE
Demande internationale no PCT/FR98/02905	Date du dépôt international (jour/mois/année) 29 décembre 1998 (29.12.98)
Déposant L'OREAL etc	

1. Le Bureau international fait savoir que l'office récepteur a, à la date indiquée ci-dessous, notifié au déposant une déclaration selon laquelle la demande internationale doit être considérée comme retirée:

30 mars 1999 (30.03.99)

2. ☐ Une copie de la présente notification a été envoyée à l'administration chargée de l'examen préliminaire international.

Bureau international de l'OMPI
34, chemin des Colombettes
1211 Genève 20, Suisse

no de télécopieur: (41-22) 740.14.35

Fonctionnaire autorisé

S. Baharlou

no de téléphone: (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

REC'D 21 DEC 1999

WIPO PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference JKH/BA/UNIBR17		FOR FURTHER ACTION See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/GB98/02905	International filing date (day/month/year) 25/09/1998	Priority date (day/month/year) 25/09/1997	
International Patent Classification (IPC) or national classification and IPC H01L33/00			
Applicant UNIVERSITY OF BRISTOL et al.			

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.


2. This REPORT consists of a total of 9 sheets, including this cover sheet.

- ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☒ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☒ Certain defects in the international application
- VIII ☒ Certain observations on the international application

Date of submission of the demand 20/04/1999	Date of completion of this report 17. 12. 99
Name and mailing address of the international preliminary examining authority:  European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Krause, J Telephone No. +49 89 2399 2829



**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT**

International application No. PCT/GB98/02905

I. Basis of the report

1. This report has been drawn on the basis of *(substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.)*:

Description, pages:

1-17 as originally filed

Claims, No.:

1-30 as originally filed

Drawings, sheets:

1/4-4/4 as originally filed

2. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
☐ the claims, Nos.:
☐ the drawings, sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

- ☐ restricted the claims.
☐ paid additional fees.
☐ paid additional fees under protest.
☒ neither restricted nor paid additional fees.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB98/02905

2. ☐ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.
3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is
- ☐ complied with.
- ☒ not complied with for the following reasons:

see separate sheet

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

- ☐ all parts.
- ☒ the parts relating to claims Nos. 1 - 18, 21 - 26, 28.

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1 - 18, 21 - 26, 28
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1 - 18, 21 - 26, 28
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1 - 18, 21 - 26, 28
	No:	Claims	

2. Citations and explanations

see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

see separate sheet

**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT**

International application No. PCT/GB98/02905

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Concerning Section IV:

1. Claims 1 to 12, 14 to 18, 21 to 26, and 28 are directed to an optical irradiation device comprising an array of light emitting diodes clustered so that radiation is directed into a beam, wherein each light emitting device is formed with multiple facets such that the facets of adjacent light emitting diodes adjoin one another in close proximity throughout their length. The problem to be solved is to allow a dense packing of the light emitting diodes.
2. Claim 13 is directed to a single light emitting diode which is adapted to be used in an optical irradiation device as claimed in one of claims 1 to 12. The features of the diode are not clear from the claim (Article 6 PCT), however, it is interpreted in the sense that the shape of the diode should be specified. In this sense, claim 13 belongs to the same invention as claims 1 to 12, 14 to 18, 21 to 26, and 28.
3. The most relevant state of the art is described in the document US-A-5 634 711, which will be referred to as D1 in the following procedure. The document describes an optical irradiation device with the features of the preamble of claim 1 (cf. column 3, line 6, to column 5, line 20, and Fig. 1).
4. Claims 19 to 26 and 28 are directed to an irradiation device employing light emitting diodes and at least two light guides. The problem to be solved by these features is to improve light collimation. The problem and its solution are completely different from those of claims 1 to 18, 21 to 26, and 28.
5. Claims 22, 27, and 28 are directed to a optical irradiation device comprising a plurality of light emitting diodes and a heat pipe to cool the light emitting diodes. The problem to be solved is to effectively remove the heat generated by the light emitting diodes. The problem and its solution are completely different from those of claims 1 to 18, 21, 23 to 26, and 28 and those of claims 19 to 21, 23 to 26, and 28.
6. Claim 29 is directed to a heat pipe and not to an optical irradiation device. Therefore the common inventive concept between claim 29 and the remaining claims is missing.

**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT - SEPARATE SHEET**

International application No. PCT/GB98/02905

7. The same objection is true with respect to claim 30, which is directed to a tapered light guide. The tapered light guide can be used with an optical irradiation device, it is however a different device, so that there is no common inventive concept with the subject-matter of claims 1 to 29.
8. As a consequence, there are the following independent inventions not linked by a common inventive concept:
 1. The optical irradiation device according to claims 1 to 12, 14 to 18, 21 to 26, and 28 and the light emitting diode therefor according to claim 13.
 2. The optical irradiation device having a plurality of tapered light guides according to claims 19 to 26.
 3. The optical irradiation device having a plurality of heat pipes according to claims 22, 27, and 28.
 4. A heat pipe having a plurality of fluid flow channels according to claim 29.
 5. A tapered light guide according to claim 30.
9. Since the applicants did not indicate on which of the inventions the examination should be based, the International Preliminary Examination Report is written on the basis of claims 1 to 18, 21 to 26, and 28, which are considered to define the main invention (Article 34(3)(c) PCT).

Concerning Section V:

I. Claim 1:

1. The document US-A-5 634 711 (= D1), which is considered to represent the most relevant state of the art, describes an optical irradiation device comprising an array of light-emitting diodes (LEDs) clustered so that radiation they emit is directed into a beam (cf. column 3, line 6, to column 5, line 20, and Fig. 1).
2. The subject-matter of claim 1 differs therefrom in that the LEDs comprise facets which adjoin each other throughout their length.
3. The document Patent Abstracts of Japan;& JP-A-8 116 093 (= D2) describes a screen comprising semiconductor LEDs. The LEDs are formed on a common substrate and have multiple facets which adjoin the facets of adjacent LEDs (cf. Figs 2, 4, 5, and 10 of the Japanese patent application). The device of the document D2 is however not an irradiation device, the emitted light is not directed into a beam. The hexagonal shape is also used to form pixels of diodes emitting light of the three basic colours.
4. The document Patent Abstracts of Japan;& JP-A-9 010 238 (= D3) describes a dental photo irradiator comprising a plurality of LEDs clustered so that the radiation they emit is directed into a beam. The LEDs do not comprise multiple facets.
5. The person skilled in the art would depart from an arrangement of LEDs as described in document D3 in an irradiation device. Since the LEDs have in general a circular cross section, a dense packing is already possible. The skilled person would therefore not readily contemplate from the knowledge of document D2 to re-shape the LEDs in the sense of document D2.
6. As a consequence, claim 1 is considered to meet the requirements of Article 33(2) and (3) PCT.

II. Claim 13:

1. Claim 13 is directed to a diode which has been modified to fit into a device according to claim 1. Claim 13 is therefore a "product-by-process" claim (cf. remarks concerning section VIII below). The LEDs described in document D2 are formed on a common substrate and are therefore not suitable for use in a device according to claim 1.
2. The idea of cutting facets into diodes to allow a dense packing is not rendered obvious by the available prior art. Claim 13 is therefore considered to meet the requirements of Article 33(2) and (3) PCT.

III. Claims 2 to 12, 14 to 18, 21 to 26, and 28:

1. Claims 2 to 12 are dependent on claim 1 and therefore comprise all the features of claim 1. Since claim 1 is considered to meet the requirements of Article 33(2) and (3) PCT, also claims 2 to 12 are considered to meet these requirements.
2. Claims 14 to 18, 21 to 26, and 28 refer to all preceding claims. This does not make sense with respect to claim 13, however, as far as these claims refer to claim 1, also claims 14 to 18, 21 to 26, and 28 are considered to meet the requirements of Article 33(2) and (3) PCT.

Concerning Section VII:

1. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the documents D1 to D3 is not mentioned in the description, nor are these documents identified therein.

Concerning Section VIII:

1. Claims 11 and 13 are directed to a device but describe the device in terms of a process for its manufacture. Such "product-by-process" claims are only clear if the process features can be unambiguously inferred from the finished device, which is apparently not the case here (Article 6 PCT).

The applicant should rather define an encapsulation of the LEDs which may be faceted. In view of the prior art the specific process of forming the facets is then no longer necessary to impart inventiveness.

2. Claims 14 to 18 and 21 to 26 should not refer to claim 13 (Article 6 PCT), because the claims do not relate to a single diode.

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference JKH/BA/UNIBR17	FOR FURTHER ACTION see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/GB 98/ 02905	International filing date (day/month/year) 25/09/1998	(Earliest) Priority Date (day/month/year) 25/09/1997
Applicant UNIVERSITY OF BRISTOL et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. ☐ **Certain claims were found unsearchable** (see Box I).
2. ☐ **Unity of invention is lacking** (see Box II).
3. ☐ The international application contains disclosure of a **nucleotide and/or amino acid sequence listing** and the international search was carried out on the basis of the sequence listing
 - ☐ filed with the international application.
 - ☐ furnished by the applicant separately from the international application,
 - ☐ but not accompanied by a statement to the effect that it did not include matter going beyond the disclosure in the international application as filed.
 - ☐ Transcribed by this Authority
4. With regard to the **title**, ☒ the text is approved as submitted by the applicant
☐ the text has been established by this Authority to read as follows:
5. With regard to the **abstract**, ☒ the text is approved as submitted by the applicant
☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this International Search Report, submit comments to this Authority.
6. The figure of the **drawings** to be published with the abstract is:
 Figure No. 4 ☒ as suggested by the applicant. ☐ None of the figures.
☐ because the applicant failed to suggest a figure.
☐ because this figure better characterizes the invention.

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 98/02905

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 H01L33/00 H01L25/13 A61C19/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H01L A61C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 191 500 A (ESPE PHARM PRAEP) 20 August 1986 see abstract ----	30
A	PATENT ABSTRACTS OF JAPAN vol. 011, no. 011 (E-470), 13 January 1987 -& JP 61 185980 A (STANLEY ELECTRIC CO LTD), 19 August 1986 see abstract; figures ----	1-3, 9, 10
A	PATENT ABSTRACTS OF JAPAN vol. 096, no. 009, 30 September 1996 -& JP 08 116093 A (FUJITSU LTD), 7 May 1996 see abstract; figures ----- -/--	1, 2, 9, 10

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

Date of the actual completion of the international search

22 January 1999

Date of mailing of the international search report

04/02/1999

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Authorized officer

De Laere, A

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 98/02905

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 013, no. 097 (E-723), 7 March 1989 & JP 63 271983 A (MITSUBISHI CABLE IND LTD), 9 November 1988 see abstract ---	
A	PATENT ABSTRACTS OF JAPAN vol. 097, no. 005, 30 May 1997 -& JP 09 010238 A (OSADA RES INST LTD), 14 January 1997 see abstract ---	1,4-7, 13,14, 19,28
A	PATENT ABSTRACTS OF JAPAN vol. 096, no. 001, 31 January 1996 -& JP 07 240536 A (SHIMADZU CORP), 12 September 1995 see abstract; figures ---	1,4, 13-15,17
A	US 5 634 711 A (KAYSER ROY ET AL) 3 June 1997 see column 3, line 38 - column 4, line 49 see column 8, line 40-48 see column 9, line 15-25 -----	1,13,14, 21, 26-28,30

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 98/02905

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0191500 A	20-08-1986	US 4723825 A	09-02-1988
US 5634711 A	03-06-1997	US 5420768 A	30-05-1995
		AU 7737894 A	03-04-1995
		CA 2149339 A	23-03-1995
		WO 9507731 A	23-03-1995